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Hsieh

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(54) **SOLUTION TO DETECTOR LAG PROBLEM IN A SOLID STATE DETECTOR**

(75) Inventor: **Jiang Hsieh**, Brookfield, WI (US)

(73) Assignee: **General Electric Company**, Schenectady, NY (US)

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Primary Examiner—Jayanti K. Patel
Assistant Examiner—Abolfazl Tabatabai
(74) *Attorney, Agent, or Firm*—Carl B. Horton, Esq.; Armstrong Teasdale LLP

(57) **ABSTRACT**

The present invention, in one form, includes a digital x-ray imaging system which, in one embodiment, collects projection data from a plurality of views and reduces artifacts caused by detector residual signals. More specifically and in one embodiment, volumetric images are generated by collecting projection data for a plurality of views. During inactive periods between the collection of projection data for adjacent views, the x-ray emission is stopped and each detector pixel is simultaneously energized to reduce a residual signal of each pixel. As a result, projection data for a subsequent view is not biased by the residual signal from a previous view.

23 Claims, 2 Drawing Sheets

Best Available Copy

FIG. 1

FIG. 2

16

118

110

114

18

FIG. 3

132   140   140

130
131

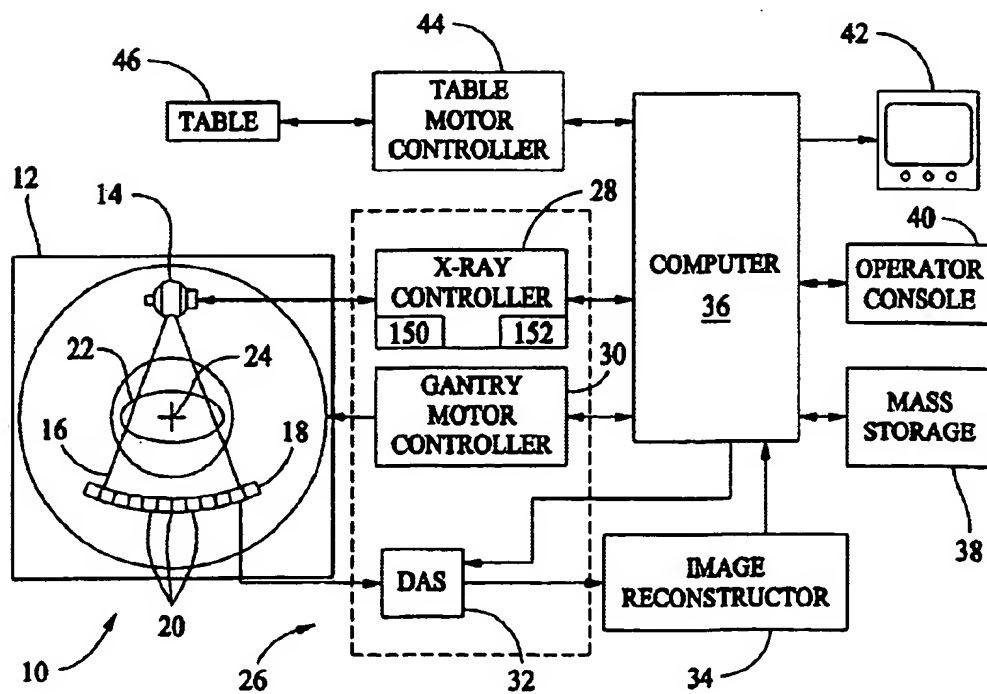134   134

120   120

110

132
131

Pitch
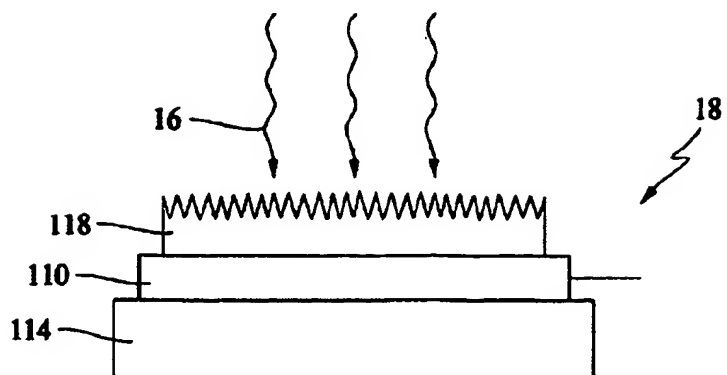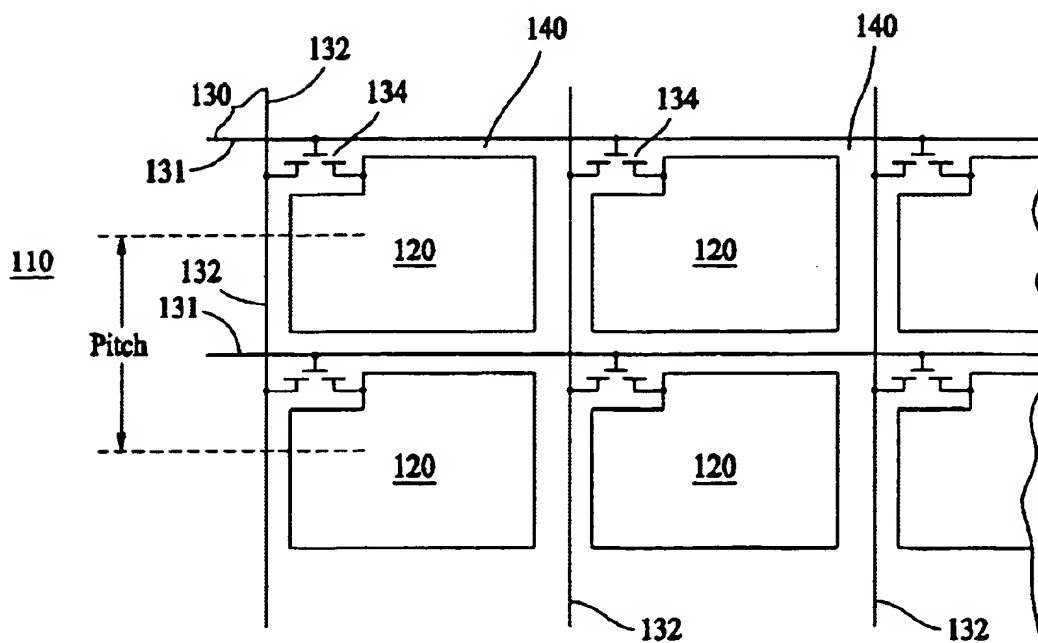
120   120

132   132

FIG. 4

SOLUTION TO DETECTOR LAG PROBLEM IN A SOLID STATE DETECTOR

BACKGROUND OF THE INVENTION

This invention relates generally to an imaging system, and more particularly, to reducing artifacts caused by detector signal lag.

In at least one known imaging system configuration, an x-ray source projects a fan-shaped beam which is collimated to lie within an X-Y plane of a Cartesian coordinate system and generally referred to as the "imaging plane". The x-ray beam passes through the object being imaged, such as a patient. The beam, after being attenuated by the object, impinges upon an array of radiation detectors. The intensity of the attenuated beam radiation received at the detector array is dependent upon the attenuation of the x-ray beam by the object. Each detector element of the array produces a separate electrical signal that is a measurement of the beam attenuation at the detector location.

In at least one known type of imaging system, commonly known as a computed tomography (CT) system, a group of x-ray attenuation measurements, i.e., projection data, from the detector array is referred to as a "view". A "scan" of the object comprises a set of views made at different projection angles, or view angles, during at least one revolution of the x-ray source and detector. In an axial scan, the projection data is processed to construct an image that corresponds to a two dimensional slice taken through the object. Typically, each slice represents less than approximately 2 cm of coverage of the patient in the patient or z-axis and is generated from data collected from 984 views during a rotation of the gantry. One method for reconstructing an image from a set of projection data is referred to in the art as the filtered back projection technique. This process converts the attenuation measurements from a scan into integers called "CT numbers" or "Hounsfield units", which are used to control the brightness of a corresponding pixel on a cathode ray tube display.

At least one known CT system collects data utilizing a large flat panel digital x-ray device, or detector, having a plurality of pixels arranged in rows and columns. However, such flat panels suffer from detector lag. The detector lag causes a significant portion of the signals from previous samples to incorrectly bias subsequent samples. A significant cause of the lag is related to the electron de-trapping resulting from the high density electronic defects in an energy gap. De-trapping times range from a few milliseconds to as long as 100 seconds. As a result of the non-uniformity of the lag, artifacts, such as rings and bands, occur in the reconstructed images.

It is desirable to provide an imaging system which utilizes a solid-state detector to generate substantially "artifact free" volumetric images. It would also be desirable to provide such a system which reduces a detector lag artifacts without significantly increasing the time required to generate the images.

BRIEF SUMMARY OF THE INVENTION

These and other objects may be attained in a digital x-ray imaging system which, in one embodiment, collects projection data from a plurality of views and reduces detector residual signals between the collection of adjacent views. More specifically and in one embodiment, the imaging system includes an x-ray source and at least one solid-state x-ray detector. To generate volumetric images, at least one

of the x-ray source and the x-ray detector are rotated around the object of interest. For each identified view, x-rays are emitted from the x-ray source toward the x-ray detector and projection data is collected for the view. During an inactive period between the collection of projection data for adjacent views, the emission of x-rays is stopped and each pixel of the detector is simultaneously energized at least once.

More specifically, during the inactive period, each scan line of the detector is simultaneously energized. The simultaneous energizing of all of the scan lines reduces a residual signal of each pixel. As a result, when projection data is collected for a subsequent view, the signal level of each pixel more accurately reflects the attenuation of the object of interest for the current view. Using the projection data collected for the plurality of views, cross-sectional images of the object of interest are generated.

Using the above described imaging system, detector lag artifacts are reduced to generate substantially "artifact free" volumetric images. In addition, the system does not significantly increase the amount of time required to generate the images.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a pictorial view of a digital imaging system.

FIG. 2 is a block schematic diagram of the system illustrated in FIG.

FIG. 3 is a schematic diagram of an x-ray detector illustrated in FIG. 1.

FIG. 4 is a schematic diagram of an x-ray detector illustrated in FIGS. 1 and 3.

DETAILED DESCRIPTION OF THE INVENTION

Referring to FIGS. 1 and 2, a computed tomography (CT) imaging system 10 is shown as including a gantry 12 representative of a "third generation" CT scanner. Gantry 12 has an x-ray source 14 that projects a beam of x-rays 16 toward a detector array 18 on the opposite side of gantry 12. X-ray beam is collimated by a collimator (not shown) to lie within in an X-Y plane of a Cartesian coordinate system and generally referred to as an "imaging plane". Detector array 18 is formed by a plurality of pixels, or elements (not shown in FIG. 1) which together sense the projected x-rays that pass through a medical patient 22. Each detector element produces an electrical signal that represents the intensity of an impinging x-ray beam and hence the attenuation of the beam as it passes through patient 22. During a scan to acquire x-ray projection data, gantry 12 and the components mounted thereon rotate about a center of rotation 24.

Rotation of gantry 12 and the operation of x-ray source 14 are governed by a control mechanism 26 of CT system 10. Control mechanism 26 includes an x-ray controller 28 that provides power and timing signals to x-ray source 14 and a gantry motor controller 30 that controls the rotational speed and position of gantry 12. A data acquisition system (DAS) 32 in control mechanism 26 samples analog data from detector elements 20 and converts the data to digital signals for subsequent processing. An image reconstructor 34 receives sampled and digitized x-ray data from DAS 32 and performs high speed image reconstruction. The reconstructed image is applied as an input to a computer 36 which stores the image in a mass storage device 38.

Computer 36 also receives commands and scanning parameters from an operator via console 40 that has a keyboard. An associated cathode ray tube display 42 allows

the operator to observe the reconstructed image and other data from computer **36**. The operator supplied commands and parameters are used by computer **36** to provide control signals and information to DAS **32**, x-ray controller **28** and gantry motor controller **30**. In addition, computer **36** operates a table motor controller **44** which controls a motorized table **46** to position patient **22** in gantry **12**. Particularly, table **46** moves portions of patient **22** through gantry opening **48**.

In one embodiment and as shown in FIGS. 3 and 4, detector **18** is a solid-state detector or radiation imager in a large flat panel configuration having a photosensor array **110** disposed on a substrate **114** and a scintillator **118** disposed on photosensor array **110**. Scintillator **118** is disposed so as to receive and absorb incident radiation, e.g., x-ray beam **16**. Scintillator **118** is optically coupled to photosensor array **110** so that optical photons generated in scintillator **118** pass into photosensor array **110**. Photosensor array **110** includes a plurality of photosensors **120**, such as photodiodes, and an addressable thin film transistor (TFT) array **130** electrically coupled to each photosensor **120**. In one embodiment, each photosensor **120** includes an amorphous silicon (a-Si) photodiode (not shown).

Addressable TFT array **130** comprises address lines **131**, **132**, typically known respectively as scan lines **131** and data lines **132**, and a plurality of charge retention TFTs **134**. Scan lines **131** and data lines **132** are arranged in rows and columns so as to divide photosensor array **110** into a plurality of pixels **140**, with one photosensor **120** disposed in each pixel **140** and electrically coupled to a respective charge retention TFT **134**, which is in turn electrically coupled to one scan line **131** and one data line **132**. Addressable TFT array **130** is configured so that each photosensor **120** is selectively and respectively addressable, that is each photosensor output (not shown) is selectively electrically coupled to its corresponding data line **132**. The radiation incident on scintillator **118** and pixel photosensors **120** measure, by way of change in the charge across the photodiode, the amount of light generated by x-ray interaction with scintillator **118**. As a result, each pixel **140** produces a digital electrical output signal that represents the intensity, after attenuation of patient **22**, of an impinging x-ray beam **16**. In this manner each photosensor **120** generates projection data. More specifically, the output signal of each respective photosensor **120** is respectively coupled to DAS **32** so that charge accumulated in each photodiode is transmitted to an input channel (not shown) of DAS **32**. In one embodiment, detector **18** is 40 cm by 40 cm and is configured to produce projection data for an entire object of interest. More specifically, each pixel **140** is approximately 200 uM by 200 uM and detector **18** includes an array of 2,000 pixelsx2,000 pixels.

In operation, at least one image of patient **22** is generated by collecting projection data from a plurality of projection, or view angles. In one embodiment, each image is generated by rotating at least one of x-ray source **14** and x-ray detector **18** around patient **22** and collecting projection data from detector **18**. More specifically and in one embodiment, a volumetric image of at least a portion of patient **22** is generated by collecting projection data from a plurality of views. Utilizing the speed limitation of detector array **18** and a scan time of 5 seconds, system **10**, in one embodiment, collects projection data from 300 views spaced approximately 1.2 degrees apart (360 degrees/300 views).

After identifying the number and location, or spacing, of the views, the projection data is collected for each view utilizing detector **18**. Specifically and in one embodiment, as at least one of x-ray source **14** and detector **18** is rotated around patient **22**, projection data is collected for each identified view. More specifically, for each identified view, control mechanism transmits an energizing signal to source **14** so that x-rays **16** are emitted from source **14** toward detector **18**. The radiation of detector **18**, specifically each pixel **140**, generates projection data for each identified view. The projection data for the identified view is then transmitted to DAS **32**. More specifically, the charge of each charge retention TFT **134** is transmitted to DAS **32**. Particularly and in one embodiment, the projection data is measured, or sampled, by sequentially enabling rows of pixels **140** by transmitting an activation signal to a corresponding scan line **131** of detector **18**. Upon receiving the activation signal, the output charge signal of each charge retention TFT **134** of the corresponding row of array, are transmitted via corresponding data lines **132** to input channels of DAS **32** and then to image reconstructor **34**. More specifically, the activation signal energizes each pixel **140** electrically connected to the energized scan line **131**. As a result, each output signal of each pixel **140** electrically connected to the energized scan line **131** is transmitted to DAS **32** via data lines **132**. This procedure is then repeated for each row of array **110** for the identified view, by sequentially energizing each scan line **131** and measuring, or sampling, the output signal of each pixel **140** of the corresponding row of array **110**.

For example, where detector **18** includes an array of MxN pixels, where M is a number of columns and N is a number of rows, projection data for a first view angle is collected by emitting x-rays **16**, at a first view angle, toward detector **18**. Output signals of pixel **140** are then measured using DAS **32**. Specifically, after energizing activation signal of row 1 via row 1 scan line **131**, the output signal of each of M data lines **132** is transmitted to DAS **32** and then to image reconstructor **34**. The activation signal of row **1** is then de-energized and the activation signal of row 2 is energized. The output signal of each data line **132** is then transmitted to DAS **32** and then to image reconstructor **34**. This process is repeated until the activation signal of the Nth row has been energized and the output signal of data lines **132** transmitted to DAS **32**. In one embodiment, where detector **18** includes 2000 rows and the sampling rate is 60 frames per second, a read-out rate for each row is 0.0083 milliseconds.

After collecting projection data for the identified view and at least one of source **14** and detector **18** continues to rotate about patient **22**, control mechanism **26** alters the signals transmitted to source **14** so that x-rays **16** are no longer emitted from source **14**. More specifically, in order to minimize blurring caused by the large angular span between views, the emission of x-rays **16** is limited to a determined period of time. For example, where it is determined that the resolution requirements require a "smearing" in a view to be less than 0.6 degrees, source **14** will emit x-rays **16** for 50% of the time between projections.

For example, if it is determined that x-ray source **14** must be enabled for approximately 0.5 degrees for each view to satisfy the resolution requirement of system **10**, x-ray source **14** is enabled for 0.5 degrees. During the time that source **14** is enabled, projection data is collected from detector **18**. Thereafter, x-ray source **14** is disabled. More specifically, the voltage and current signals are removed, or altered, so that x-ray beam **16** is no longer emitted from source **14**.

In one embodiment, x-ray controller **28** includes a power supply **150** and a switching unit, or circuit **152**, as known in the art, to alter the signals supplied to source **14**. Power supply **150** is coupled to x-ray tube **14** and switching unit **152** to supply signals to source **14** and unit **152**. More

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particularly, voltage and current signals from supply 150 are supplied to an anode (not shown) and a cathode (not shown) of source 14. A high voltage signal is also supplied from supply 150 to switching unit 152. If x-ray beams 16 are to be emitted, the proper voltage and current signals are transmitted to x-ray source 14. More specifically, utilizing control signals (not shown) supplied to switching unit 152, for example, signals from computer 36, switching unit 152 alters the signals supplied to source 14. More specifically, by altering the control signals, the signal supplied to a control grid (not shown) of source 14 is altered so that the speed at which the electrons travel from the anode to the cathode is modified, therefore, altering the magnitude and duration of x-ray beams 16 emitted from source 14. As a result, the emission of x-rays 16 may be started or stopped at specific, or defined, periods of time.

During the period of time that x-rays 16 are not emitted from source 14 between adjacent views, referred to as an inactive period of time, each pixel 140 maintains a portion of the output signal generated for the view last collected. This signal is defined as a residual signal of detector 18. The residual signal results from "detrapping" of interband states in the semiconductive material (not shown) of a switching device of each pixel 140, such as a FET (not shown) after the FET is turned off, e.g.,the time period when a signal is not desired from pixel 140.

System 10 reduces the artifacts caused by the residual signal by reducing the level of the residual signals during the time between adjacent views when x-ray source 14 is disabled (e.g., during the inactive period). Specifically and in one embodiment, during the inactive period, the residual signal of each pixel 140 is reduced by energizing, or enabling, a plurality of rows of each detector 18 at least once. More specifically and in one embodiment, activation signals are simultaneously transmitted, at least once, to each pixel 140 via each scan line 131. Depending upon the amount of time available during the inactive period, the simultaneous transmission of the activation signals each scan line 131 is repeated a plurality of times. Each time scan lines 131 are simultaneously transmitted to detector 18, the residual charge of each pixel 140 is reduced. In one embodiment, the residual charge of charge retention TFT 134 is reduced as a function of 1/S, where S is a number of samples. As a result of the simultaneous transmission of the activation signals, the residual signal of each pixel 140 of detector 18 may be rapidly reduced.

For example, where detector 18 includes a 2,000 column by 2,000 row array of pixels 140 and activation signals are simultaneously applied to all 2,000 scan lines 131 twenty times, once every 0.0083 milliseconds, during the inactive period, the residual signal of each charge retention TFT 134 is reduced to approximately 5% of its original strength.

In one embodiment, the accuracy of the projection data collected for each view is corrected utilizing a lag correction value. More specifically, based upon the number of times each scan line 131 is simultaneously enabled, a lag correction value may be determined and combined with the collected projection data to further reduce the image artifacts caused by the residual signals. In various embodiments, the lag correction value is based on actual historical data, estimated values, or mathematical calculations for each detector 18.

At the end of the inactive period, the above described process is repeated for each view until projection data has been collected for each identified view. The collected projection data is then utilized, in a manner known the art, to

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generate at least one image of an object of interest, for example a portion of patient 22. More specifically, and in one embodiment, cross-sectional images of the object of interest are generated from the projection data. In another embodiment, the corrected projection data is utilized to generate the images of the object of interest.

The above described system reduces artifacts caused by charge retention of a solid-state detector array. Particularly, by simultaneously energizing each scan line of the detector array, the residual signal of the detector is reduced .

While the invention has been described in terms of various specific embodiments, those skilled in the art will recognize that the invention can be practiced with modification within the spirit and scope of the claims. For example, although the present invention was described in use with a CT system, the invention may be practiced with many other types of imaging systems.

What is claimed is:

1. A method for reducing image artifacts in an imaging system, the imaging system including an x-ray source for emitting an x-ray beam and at least one solid state x-ray detector, said method comprising the steps of:

collecting projection data for a plurality of views; and

reducing residual signal levels of each detector between adjacent views wherein reducing the residual signal levels comprises:

disabling the x-ray source between collection of projection data for adjacent views; and

applying at least one activation signal to each dector.

2. A method in accordance with claim 1 wherein collecting projection data for a plurality of views comprises the steps of:

identifying each view; and

enabling the x-ray source and collecting projection data for each identified view using each detector.

3. A method in accordance with claim 2 wherein enabling the x-ray source and collecting projection data for each identified view using each detector comprises the steps of:

determine whether x-ray beams are to be emitted from the x-ray source; and

if the x-ray beams are to be emitted, provide a voltage and current signal to the x-ray source.

4. A method in accordance with claim 1 wherein each detector includes a plurality of pixels arranged in an array of M rows and N columns, and wherein applying at least one activation signal to each detector comprises the step of applying an activation signal to each pixel of each detector.

5. A method in accordance with claim 4 wherein each digital detector includes M output signals and N activation signals, and wherein applying an activation signal to each pixel of each detector comprises the step of a) enabling all N activation signals of each detector simultaneously.

6. A method in accordance with claim 5 further comprising the step of repeating step a) at least once.

7. A method in accordance with claim 5 further comprising the step of repeating step a) a plurality of times.

8. A method in accordance with claim 5 wherein M equals 2000 and N equals 2000.

9. A method in accordance with claim 1 further comprising the step of correcting the projection data utilizing a lag correction value for each detector.

10. A method in accordance with claim 9 further comprising the step of generating cross-sectional images of an object of interest using the corrected projection data.

11. An imaging system for reducing image artifacts, said imaging system comprising an x-ray source for emitting an

x-ray beam and at least one solid state x-ray detector, said system configured to:

collect projection data for a plurality of views; and

reduce residual signal levels of each said detector between adjacent views.

12. A system in accordance with claim 11 wherein to collect projection data for a plurality of views, said system configured to:

identifying each view; and

enable said x-ray source and collect projection data for each identified view using each said detector.

13. A system in accordance with claim 12 wherein to enable said x-ray source and collect projection data for each identified view using each said detector, said system configured to:

determine whether said x-ray beams are to be emitted from said x-ray source; and

if said x-ray beams are to be emitted, provide a voltage and current signal to said x-ray source.

14. A system in accordance with claim 12 wherein each said detector includes a plurality of pixels arranged in an array of M rows and N columns, and wherein to apply at least one activation signal to each said detector, said system configured to apply an activation signal to each said pixel of each said detector.

15. A system in accordance with claim 14 wherein each said detector includes M output signals and N activation signals, and wherein to apply an activation signal to each said pixel of each said detector, said system configured to enable all N said activation signals of each said detector simultaneously.

16. A system in accordance with claim 15 further configured to enable all N said activation signals of each said detector simultaneously at least once.

17. A system in accordance with claim 15 further configured to enable all N said activation signals of each said detector simultaneously a plurality of times.

18. A system in accordance with claim 15 wherein M equals 2000 and N equals 2000.

19. A system in accordance with claim 11 further configured to correct said projection data utilizing a lag correction value for each said detector.

20. A system in accordance with claim 19 further configured to generate cross-sectional images of an object of interest using said corrected projection data.

21. A method of reducing a lag signal in a detector array, the detector array includes a plurality of pixels arranged in columns and rows, each column of pixels electrically connected to a pixel output signal, each row of pixels electrically connected to a pixel activation signal, said method comprising the steps of:

a) enabling a pixel activation signal for a row of the detector array;

b) measuring a pixel output signal for each pixel corresponding to the enabled row; and

c) repeating steps a) and b) for each row of the array; and

d) simultaneously enabling each pixel activation signal of the detector array at least once.

22. A method in accordance with claim 21 wherein the detector array includes M columns and N rows, and wherein simultaneously enabling each pixel activation signal of the detector array at least once comprises the step of simultaneously enabling N pixel activation signals at least once.

23. A method in accordance with claim 22 wherein simultaneously enabling each pixel activation signal of the detector array at least once comprises the step of simultaneously enabling N pixel activation signals a plurality of times.

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